JSACE 1/10

Received 2014/06/30

Accepted after revision 2015/02/12

Usage of the Wind Energy for Heating of the Energy-Efficient Buildings: Analysis of Possibilities

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http://dx.doi.org/10.5755/j01.sace.10.1.7479

The paper analyzes and compares the energy demand for heating purpose of new buildings with different energy perfomance rates. Article studies global renewable energy sources innovations, statistics and scientific and engineering experience to ensure the building's thermal energy needs, produced by transforming wind energy.

Distribution of the potential of one renewable source – wind energy – during the year is similar to the energy necessary for the building heating, thus production of the heating energy from mechanic energy of the wind is chosen for further scientific investigations. Wind power plant, generating 2 kW of heat power, installed as a heating source for the analysed individual house, can cover from 40 to 76% annual heat needs of the building, subject to its energy-efficiency class, respectively 1.5 kW – from 31 to 68%, 1 kW – from 22 to 53%.

KEYWORDS: energy efficiency, energy conversion, heating, wind energy.

Introduction

There are no doubts that the energy saving, its efficient usage and searches of the new methods of the energy production are very topical by many aspects. The burning of fossil fuels influence the greenhouse gas emissions (CO_2, CH_4, N_2O, etc..), that gives impact on the planet's atmospheric composition. In order to solve this problem, the global community adopted United Nation's Framework Convention on Climate Change, which commits to reducing greenhouse gas emissions.

EU countries have set the goals that are easy to remember in this area: by 2020 – 20% reduction in energy consumption, 20% reduction in greenhouse gases discharged to the environment and to produce 20% of all necessary energy from the renewable sources (Energy Efficiency Directive 2012/27/EU).

Many countries shall find that besides the above mentioned arguments the economic aspect is topical as well – i.e., in the countries, where the residents spend proportionally bigger part of the family budget for the accommodation heating (eg, in the 2013 Lithuanian Ministry of Environment ordered a survey where 35% of Lithuania's population has indicated that at the end of the last heating season their home heating costs accounted for 16-30% of monthly income), and in the countries that spend significant part of the budget for the fuel import, energy saving is the matter-of-course by the extent of the country and the separate households. In comparison - in 2010, for

Journal of Sustainable Architecture and Civil Engineering
Vol. 1 / No. 10 / 2015
pp. 58-65
DOI 10.5755/j01.sace.10.1.7479

gas, electricity and oil, Lithuania paid about 2,3 bill. Eur per year, while the whole Lithuanian state budget amounted 5,2 bill. Eur.

Building heating in Lithuania consumes 23% of the total consumption of primary energy (Lietuvos šilumos tiekėjų asociacija, 2010). As the consumed part is significant, big attention is paid to the designing and construction of the new energy-efficient buildings. At the moment, STR 2.05.01:2013 "Designing of the Energy-Efficiency of the Buildings" approved in Lithuania shall determine the requirements for energy-efficiency classes of all new buildings. Class of the energy-efficiency – building evaluation, including many aspects:

- Thermal characteristics of the building partitions,
- Building tightness that is the characteristic of the construction work quality very often,
- Usage efficiency of the non-renewable (primary – oil, natural gas, coal, peat) and renewable (wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogas) energy sources that is related to the systems installed in the building, their automatic adjustment and energy saving at the same time.
- This article shall analyse the opportunities to produce a part or all necessary heating energy in the building using the renewable sources in more detail. Very often this topic is evaluated sceptically, because of the thinking that energy needs of the buildings are conditionally big, and potential of the renewable sources is small. Therefore, analysis of the heating needs and possibilities meeting them using wind energy should decrease scepticism and form further tasks at issue, in order to develop implementation of the alternative energy sources both, in the sense of quantity and quality.

Methods

120 m^2 living house designed according to the principles of the energy-efficiency has been chosen for the analysis (Fig. 1). Building has two floors; transparent partitions (windows and doors) shall make 19% of the area of all vertical partitions, and 64% of them is oriented to the South.

A few calculation variants have been made – when the building partitions meet requirements of the energy-efficiency class "B", "A", "A+" and "A++". Designed heat needs for the building heating have been calculated by evaluating the heat losses through the building partitions, heat need for the building mechanic ventilation and losses due to the outside air infiltration. In addition, the inflows from the people, electric lighting system and home electric appliances and due to the solar radiation have been evaluated.

In order to meet the air quality conditions regulated by the hygiene standards, the calculations shall analyse the building that has the mechanic ventilation system installed, although, according to the valid construction technical regulations, such system is not obligatory to all variants of the energy-efficiency classes analysed.

Fig. 1

Building visualization – upper: South Western façade; lower: North Eastern facade (source - www.haus.lt, project author - arch. A. Zaniauskas)

It is considered that average temperature in the rooms is +20°C (during working days for 9 hours and during weekends for 6 hours per day – +18°C, and during working days for 15 hours and during weekends for 18 hours per day – +21°C). Calculations have been made according to the climatology data of Kaunas city.

Results

Calculation has been made according to STR 2.09.04:2008 "Capacity of the building heating system. Heat need for heating". Results of the calculations shall be provided in the table 1–3.

In this case, losses due to the external door opening/closing have not been evaluated, although, there is no doubt that such losses are conditioned by the building exploitation. It is more rational applying the passive solutions for compensation of the heat losses through the door – hood without automatic quantitative regulation, i.e., such system that will not react to the cooled air of the premises due to the opened door and will not increase the amount of heat supplied to the room. When the door is opened, hood temperature for the specific area shall decrease, but this does not condition the general comfort of the building residents significantly.

After comparison of the building heat losses through the partitions and losses due to the ventilation system, the tendency that when energy-efficiency of the building increases, the percent distribution changes and is almost equal to the buildings having the biggest energy-efficiency (A++ class) (6578kWh/5453kWh – 55%/45%). Thus, we can make the implication that bigger attention will be paid to the development of the ventilation system equipment of the building and management and automation of such systems in the future.

Heat inflow to the building due to the solar radiation can be analysed in more detail, as this free heat shall make the biggest part of the internal inflows – 65-77% (for the analysed building). In order to design energy-efficient buildings, special attention shall be paid to the selection of the window width

Table 1

Heat losses through the building partitions Q_{en}, kWh

	Energy-efficiency class of the building			
Month	B	A	A+	A++
January	3204	1574	1333	1130
February	2827	1375	1157	978
March	2656	1284	1077	909
April	1859	861	703	584
May	1119	466	355	281
June	678	230	146	100
July	546	158	82	44
August	590	180	101	60
September	1084	443	333	261
October	1691	766	618	509
November	2262	1070	887	743
December	2840	1379	1160	980
In total:	21356	9786	7953	6578

Table 2

Heat losses due to the mechanical ventilation (including infiltration of the outside air) Q_v, kWh

	Class of the building energy-efficiency/coefficient of the efficiency of the heat recovery equipment			
Month	B/0,65	A/0,65	A+/0,8	A++/0,9
January	1222	1222	1003	858
February	1064	1064	874	747
March	989	989	812	694
April	666	666	547	467
May	368	368	302	258
June	196	196	161	138
July	150	150	123	105
August	174	174	143	122
September	380	380	312	266
October	625	625	513	439
November	854	854	701	599
December	1081	1081	888	759
In total:	7769	7769	6380	5453

and glass pack construction. There is a need to decide objectively, what window size and construction are the most rational, as the heat energy through the windows is lost and got due to the solar radiation.

Calculations that are used when increasing the window width in the facades oriented to the different world sides shall be provided in the tables 4-8 (decreasing area of the outside walls appropriately). Months of heating season (October-April) shall be chosen for the analysis, i.e., when the outside temperature is less or equal to +10°C and the internal building releases do not compensate the heat losses. When performing the calculation, difference of the heat transfer coefficient of the window U_W and wall, coefficient of the skip of the aggregate solar energy g and coefficient F_c allowed evaluating the effect of the solar protection means.

Detail analysis has revealed that in some cases the building project can be changed by increasing the window areas in such facades, where the solar radiation intensity is the biggest. In the buildings that coefficients of the heat transfer of the walls and windows shall meet the standard values of A+ and A++ classes of the buildings, it is rational to maximally increase the area of the windows in the Southern facade, as the windows oriented to the South during heating season shall pass the heat energy to the rooms more due to the effect of the solar radiation, compared to the heat losses (numbers in green boxes indicate reasonable solution, in yellow – close to reasonable solution result). Southern facade of the analysed building has been used effectively to this point, but when transferring part of the windows designed in the North side to the Western and Eastern facade, characteristics of the premises' lighting shall not decrease and the heat inflows would be bigger. In the buildings, where coefficients of the heat transfer meet standard values of the buildings of class A, area of the windows should be increased, if it is possible decreasing area of the window with the solar protection means or not using such means during the heating season (table 8).

Aim of the calculations provided above – to optimise the architectural solutions of the building and to determine needs of the heating system (Fig. 2) for the energy-efficient

Table 3

Heat inflow to the building from the people, lighting and home electric appliances Q_{ig}, kWh

Month	For all energy-efficiency classes
January	202
February	182
March	199
April	190
May	188
June	182
July	188
August	188
September	190
October	199
November	195
December	202
In total:	**2307**

Table 4

Part of heat losses through the windows covered by the heating system (+) and solar radiation (-) in the building of energy-efficiency class B, % (*Uw* - 1.6, g - 0.53, *Fc* – 0.8)

Month	N	E	S	W
January	88	87	73	87
February	74	71	51	70
March	49	35	2	33
April	22	-10	-34	-5
October	64	51	11	53
November	89	87	72	87
December	92	91	79	91
In total:	**71**	**64**	**42**	**64**

Table 5

Part of heat losses through the windows covered by the heating system (+) and solar radiation (-) in the building of energy-efficiency class A, % (*Uw* - 1, g - 0.48, *Fc* – 0.8)

Month	N	E	S	W
January	82	81	60	80
February	61	58	28	56
March	25	4	-45	1
April	-15	-62	-98	-55
October	48	28	-30	31
November	83	81	59	81
December	88	87	69	86
In total:	**58**	**46**	**15**	**47**

Table 6

Part of heat losses through the windows covered by the heating system (+) and solar radiation (-) in the building of energy-efficiency class A+, % (*Uw* - 0.85, g - 0.48, *Fc* – 0.8)

Month	N	E	S	W
January	79	77	52	77
February	54	50	15	48
March	11	-14	-72	-17
April	-36	-93	-135	-85
October	38	14	-55	18
November	80	77	51	77
December	85	84	63	84
In total:	**50**	**36**	**-1**	**36**

Table 7

Part of heat losses through the windows covered by the heating system (+) and solar radiation (-) in the building of energy-efficiency class A++, % (*Uw* - 0.7, g - 0.48, *Fc* – 0.8)

Month	N	E	S	W
January	74	72	41	71
February	43	38	-5	35
March	-10	-40	-112	-45
April	-68	-138	-190	-128
October	23	-6	-91	-1
November	76	72	40	72
December	82	80	55	80
In total:	**38**	**21**	**-25**	**22**

Table 8

Part of heat losses through the windows covered by the heating system (+) and solar radiation (-) in the building of energy-efficiency class A, % (*Uw* - 1, g - 0.48, *Fc* – 1.0)

Month	N	E	S	W
January	77	76	50	75
February	52	47	10	45
March	7	-19	-81	-23
April	-43	-103	-147	-94
October	35	9	-63	14
November	79	76	49	76
December	85	83	62	83
In total:	**47**	**33**	**-6**	**33**

buildings and rational capacity of the alternative heat source of such buildings. In addition, calculations shall allow checking, if the wind energy can guarantee the heat quantity (or its part) necessary for the building heating.

Calculations performed shall indicate that average need of the moment energy for heating is from 5 kW (for typical family house of energy-efficiency class B) to approx. 2 kW (for typical family house of energy-efficiency class A++). In addition, due to variability of the wind energy (as any other alternative energy source), a possibility to produce only part of energy necessary for the building heating by transforming the wind energy shall be analysed, as in any case the source guaranteeing the appropriate heating energy supply should be installed in the building in parallel (biofuel, gas fuel boiler; unit of the centralized heating networks or electric heating system, using electric power from the centralized networks).

If the wind power plant, generating 2 kW of heat power, is installed for the analysed case, it would be possible to cover from 40 to 76% annual heat needs of the building, subject to its energy-efficiency class, respectively 1.5 kW – from 31 to 68%, 1 kW – from 22 to 53%.

Wind energy application for the building heating has been chosen due to a few reasons:

1 distribution of the wind energy potential during a year is closer to the heating needs of the building, compared to the solar radiation energy used widely – it is due to the fact that wind power is directly dependent on the wind velocity and air density (Adomavičius V., 2013) – average wind velocity is bigger in winter than in summer in Lithuania (Adomavičius V., 2011) (Fig. 3) and density of the cold air is bigger than warm air;

2 much bigger availability of the wind energy for the individual houses, compared to the hydro-energy;

3 during exploitation wind energy does not release pollution (f.e. like during combustion of biofuel) to the environment.

Fig. 3 shall present average values of the wind speed (Galvonaitė A., 2013), they cannot be used when making implications on the wind energy potential in the specific land plot. For this purpose, annual measurements of the wind speed in the land plot should be performed (Marčiukaitis M., 2009). Theoretically, it is possible to model speeds of the wind in the specific land plot and surrounding territories, but network of the stations for the wind speed measurement is conditionally small (in Lithuania wind speed is being measured in 18 stations in the height of 10 m) and work extent of such modelling would be unjustified big.

In order to perform primary evaluation of the system "wind power plant – heat generator", the calculations have been performed; they have revealed that in case of average wind speed of 4 m/s (for example, it is the average annual wind speed in Lithuania), in order to generate 1 kW of heating energy, three-vane wind turbine with horizontal axis of diameter 8.22 m that power factor is cp=0.49 shall be needed (Kytra S., 2006).

The analyzed living house, which is equipped with wind turbine of 1 kW power and which can manufactured from 3433 kWh (A + + energy efficiency class of the building) to 4241 kWh ("B" energy

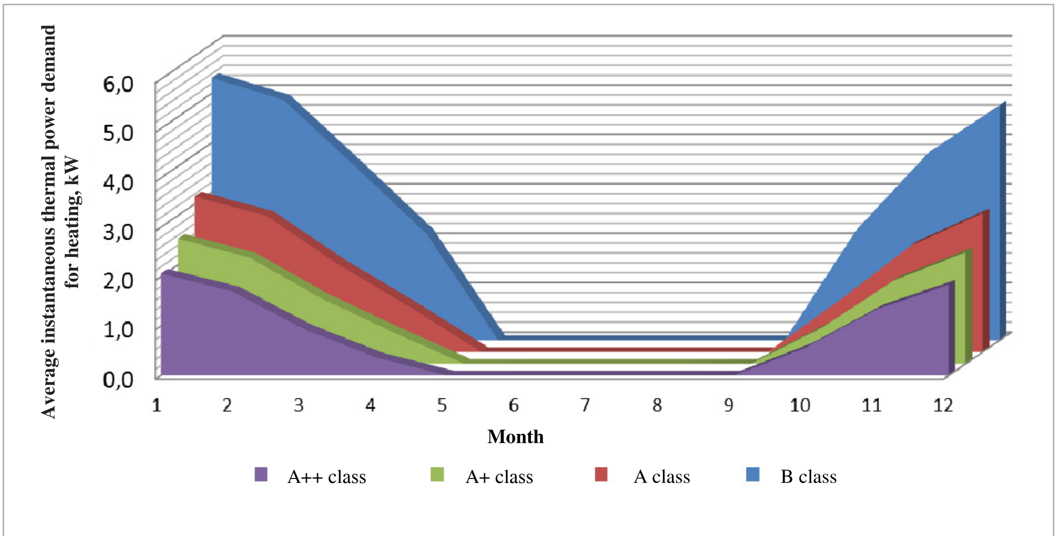

Fig. 2

Average instantaneous thermal power demand for heating of the analysed buildingof different energy-efficiency classes during the year

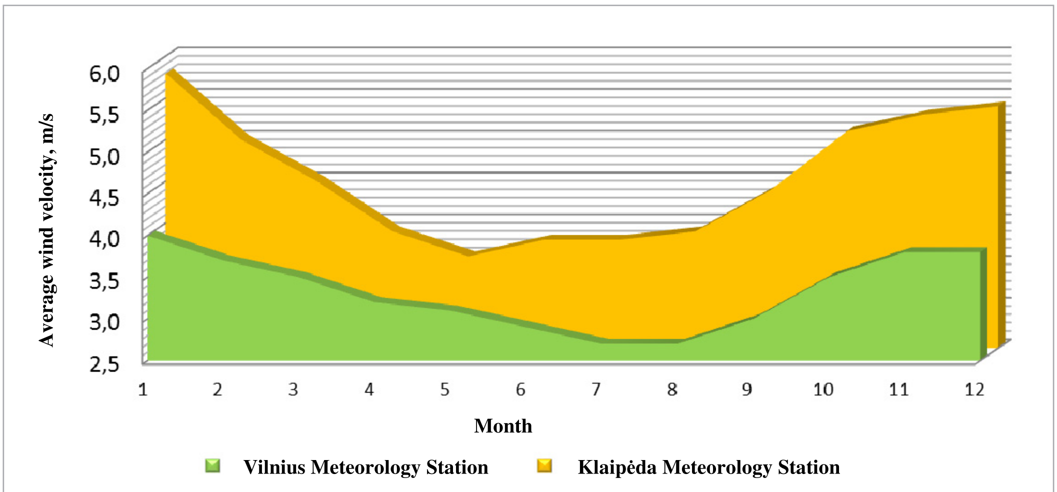

Fig. 3

Distribution of the average wind velocity during a year according to the data of 1981-2010 efficiency class of the building) thermal energy, protects the atmosphere of not throwing in the environment up to 856 kg of greenhouse CO_2 gas (as compared to natural gas combustion for heating), which is the CO_2 "footprint" equivalent to about 4000 km journey by car. CO2 treatment is relevant because it accounts for about 95% of the total greenhouse gas structure (Konstantinavičiūtė I., 2012).

Discussion

Principles of the heat production directly from the mechanic wind energy have been already described in the previous works of the engineers and scientists. In most cases equipment of such type is based on the usage of the volume hydraulic machines (pumps), where the kinetic energy of the wind wheel axis is transferred to the potential fluid energy, and due to the artificial obstacle and friction to it the fluid potential energy is transferred to the heat energy (Maegaard P., 2013). In 1960 V. V. Blasutta and J. F. Hedge ("Fluid pressure energy translating device", USA) and in 1981 – W.J. Grenier ("Fluid friction heater", USA) have described and patented the device of such type. In 1983 J. E. Knecht ("Wind driven heating system", USA) and in 1986 H. W. Haslach ("Wind turbine heat generating apparatus", USA) have patented devices of the analogous type that suggested using heat generated due to the fluid friction and have used the wind wheel as the source of the primary energy. We can state that such interest in the alternative energy in the eight-ninth decade of XX century could be conditioned by the world oil crisis of 1973, when big part of people has felt significant shortage of the fossil fuel.

In addition, input of the Danish scientists and technical enthusiasts to the development of the wind power plants producing heat can be noticed. Nowadays and in the eight decade of the last century Denmark was the leader in the area of the wind energy usage. In 1973 engineers S. S. Kofoed and R. Matzen from the Institute of the Agriculture Engineering (Taastrup, Denmark) has created, tested and developed the wind power plant "Mark" (version "Mark I" and "Mark II"), producing heat energy from the wind mechanic energy. Later, H. H. Ekner has created the wind power plant "Calorius" that has gained an attention from the scientists as well – capacity and noise level tests have been performed for the power plant of such construction and in 1993–2000 Danish company "Westrup" has installed and started 34 power plants "Calorius" (according to 2012 data, 17 of them are still used). Although a lot of scientists and engineers see a lot of benefits of the wind power plants producing heat, but power plants of such type has not been used widely in practice. We can make assumptions that there was a lack of subsidies from the national funds, provided to the production of the electricity from the wind energy.

In Lithuania possibilities to use the wind energy have been explored in more detail and various publications prepared in A. Stulginskis University (former University of Agriculture of Lithuania). Firstly, instalment of the equipment for using the wind energy has been topical in the localities distant from the centralized networks, thus the scientists of this university have paid bigger attention to this topic. In 2001 in the Institute of the Agriculture Engineering of the Lithuanian Agriculture University A. Gulbinas has prepared and defended doctor's dissertation on the topic "Investigation of the effective usage of the wind energy equipment in the agriculture". In addition, in 2011 A. Kavolynas has defended the doctor's dissertation in A. Stulginskis University on the topic "Solar and wind energy usage for meeting the heat needs of the buildings in the rural localities", however, in this work the author has paid more attention to the investigation of usage of the solar energy and its accumulation, and the topic of wind energy has been analysed according to the works of other authors.

A lot of international organizations work in the area of the wind energy usage – Global Wind Energy Council (GWEC) represents over 70 countries; European Wind Energy Association (EWEA), established in 1982 in Belgium and having 600 members from almost 60 countries; World Wind Energy Association (WWEA) – established in Germany and having 95 members. Lithuanian Wind Energy Association (LWEA), established in 2005, is the member of the international organizations as well. LWEA pays the biggest attention to the development of the electricity production in the wind power stations.

Conclusions

Distribution of the potential of one renewable source – wind energy – during the year is similar to the energy necessary for the building heating, thus production of the heating energy from mechanic energy of the wind shall be chosen for further scientific investigations.

Wind power plant, generating 2 kW of heat power, installed as a heating source for the analysed individual house, can cover from 40 to 76% annual heat needs of the building, subject to its energy-efficiency class, respectively 1.5 kW – from 31 to 68%, 1 kW – from 22 to 53%.

The heat power of 1 kW can be performed in the system "wind power plant – heat generator" with three-vane wind turbine with horizontal axis of diameter 8.22 m in case of average wind speed of 4 m/s.

The following area still lacks unbiased quantitative evaluation of the effectiveness, so this fact may restrict implementation of such systems practically.

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